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Research Article

Assessment Model for Water Quality Progression of Gia, Re, and Da Do River for Drinking Water Purpose in Hai Phong City

An Thi Hoang[1]*, Hang Thi Dieu Tran[1], Anh Phuong Tran[1], Nam Anh Nguyen[1], Tu Van Tran[1], Chung Bao Tran[1]

[1] Water Resources Institute, Ministry of Natural Resources and Environment; Anht510@wru.vn; hangtd1001@gmail.com; phuongtran.monre@gmail.com; namanh.luna@gmail.com; trantuvfu@gmail.com; ChungTB26@wru.vn

*Corresponding author: anht510@wru.vn; Tel.: +84–963952484

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Abstract: Gia, Re, and Da Do Rivers are the main surface water resources providing fresh water to the habitants of Hai Phong City. They are at risk of water pollution due to the release of multiple waste streams along the rivers. The main objective of this study is to establish water quality models for Gia, Re, and Da Do Rivers using the MIKE 11 Ecolab model. The studied pollutants include BOD_5, NH_4^+, NO_3^-, DO, etc. Pollution trends can be predicted using pollutant load generation in the water quality model. The simulation results give relatively high correlation coefficients (0.8–0.88) and the relative error of 4–18% ensures the quality of the model. Concurrently, the research team calculated the water quality index (WQI) in the 2020 dry season for eleven locations on three rivers Gia, Re and Da Do based on the following parameters: T, pH, COD, BOD_5, NH_4^+, NO_3^-, DO, As, Pb, Coliform, E. coli, etc. WQI results, with the combination of field observation and simulations, show that the water quality of Gia River is very good of Re river is an average; while the water quality of Da Do River decreases gradually from upstream at a good level to downstream at an average level. These WQI results provide a high–level assessment of the river water quality, which will assist the management of surrounding wastewater treatment systems to maintain the supply of water purpose of these three rivers to Hai Phong City.

Keywords: Water Quality; MIKE 11 Model; WQI; Gia River; Re River; Da Do River.

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1. Introduction

Water is a finite resource which plays an important role in life, in which water quality is always the most urgent matter of concern. Hai Phong is a city located in the coastal estuary region, downstream of the Red – Thai Binh River system of Vietnam. The city's water quality is affected simultaneously by the impact of polluting activities in the localities located in the upper reaches of the rivers as well as within the city [1]. In addition, because it is located in the estuary and coastal areas, the water source is always at risk of saltwater intrusion from the sea, and this tends to become more and more serious due to the influence of sea level rise. The city's fresh water supply is being taken mainly from the three main freshwater rivers of Hai Phong, namely the Re River, Gia River, and Da Do River. The water of Gia, Re, and Da Do Rivers is monitored and sampled by the Environmental Monitoring Center quarterly, with the analytical parameters [2]. According to the monitoring results until September 2020, most of the rivers show signs of pollution by nutrients and organic substances such as N, P, BOD_5, and Coliform.

Pollution loads exceeding national standard degrade water quality and negatively impact local economies and human health. With this issue, a good assessment and implementation of the water quality controls will contribute greatly to the protection of water resources, ensuring the harmony between economic development and environmental protection. In water quality assessment, mathematical models play a central role. These models provide both spatial and temporal high-resolution water quality information as well as assess the ranges of water quality under different scenarios of socio-economic development and environmental protection. Mathematical models were built to simulate water quality parameters and the dispersion of pollutants in water bodies. There are a variety of models on the market that can be used to model the hydrodynamic process on river systems, allowing the simulation of water quality progression, and the evaluation of the control measures effectiveness, for instance, SWAT, Tuflow, HEC RAS, HSPF, WASP, QUAL2E, QUAL2K, RWQM, MIKE, and QUASAR. Various controls help decision–makers identify the most effective water quality control [3].

In a review by [3], the Ministry of Environment of South Korea prepared a joint plan for water environment management in 2006, which detailed six water quality forecasting models and recommended a series of numerical models including Widely used Qual2E and EFDC model. Meanwhile, MIKE model and Tuflow model have been widely applied to predict surface water quality in Australia. MIKE models have also been adapted in Denmark to address several problems in these areas such as ecology, environmental chemistry, water resources, hydraulic engineering and hydrodynamics. In China, the Delft 3D dynamic water quality model has been used to simulate water quality in Hong Kong since the 1970s and has now become the standard model of the Hong Kong Environment Agency [4]. Specifically, [5] used the QUAL2K model to simulate and forecast river water quality under different flow scenarios, serving to develop water quality management measures for each scenario in the Kaoping River basin Taiwan. [6] used the MIKE 11 and EcoLab models to evaluate the effectiveness of water quality management measures in the Lao Hewan basin, China. In the latest study in 2022, the water quality of the Sinú River, Colombia was evaluated by author Torres – Bejarano of water quality through different seasons using Environmental Fluid Dynamics Code (EFDC) software based on the construction of a hydrodynamics and water quality model [7–8] used the QUAL2E model to assess the risk of water quality pollution when untreated water is discharged directly into the water source in the Balatuin River (Philippines). [9] used MIKE 11 and EcoLab models to evaluate the effectiveness of water quality management measures in the Lao Hewan basin, China. [10] used MIKE model to simulate the level of nitrates using MIKE 11 and to establish relationship between nitrogen and phosphorus.

Meanwhile in Vietnam, there have been several studies using mathematical models for water quality estimation. In Ca Mau peninsula study by [11], a coupled 1D and 2D hydraulic and water quality model is applied for the east and west coastal estuaries; a 2D model is used to assess and test water quality in twelve coastal estuaries [11–12] used MIKE 11 Ecolab and Artificial Intelligence model to simulate water quality of Nhue–Day River in Ha Noi city. [13] used MIKE 11 Ecolab to model assessment and forecast of water quality in canals, rivers and streams in Binh Duong province. [14] used application of a one–dimensional hydrodynamic model HEC–RAS to simulate hydraulic properties (flow and water level) and water quality in the Xang Channel, the Soc Trang city.

The application of mathematical modeling tools in water resource management has been applied more and more widely in Vietnam and other countries. This is considered the most effective means because it allows decision makers to know the consequences of each pollution control measure in advance. The MIKE 11 Ecolab mathematical model is becoming a powerful tool for water quality management due to its outstanding advantages including fast calculation, flexibility in changing scenarios or both large and small river basins. Considering these different studies, the MIKE 11 Ecolab model was selected by the research team to simulate spatial and temporal progression of water quality in Gia, Re, and Da Do Rivers for further management decisions of Hai Phong city drinking water supply.

2. Research methods and data collection

2.1. Description of the study area

Gia River is the main canal route of Thuy Nguyen irrigation system, with a length of 16.5 km, starting from Phi Liet sluice (Lai Xuan commune, Thuy Nguyen district) and ending at Minh Duc dam (Minh Duc town, Thuy Nguyen district) (Figure 1). The replenishing water source for Gia River comes from Da Bac River through Phi Liet sluice (Lai Xuan commune), Kinh Thay River through An Son sluice (An Son commune); and several other drains. The main functions of Gia River are irrigation for agricultural production; raw water supply for drinking water treatment; prevention of floods and droughts; waste sources recipients; and ecosystem protection [1].

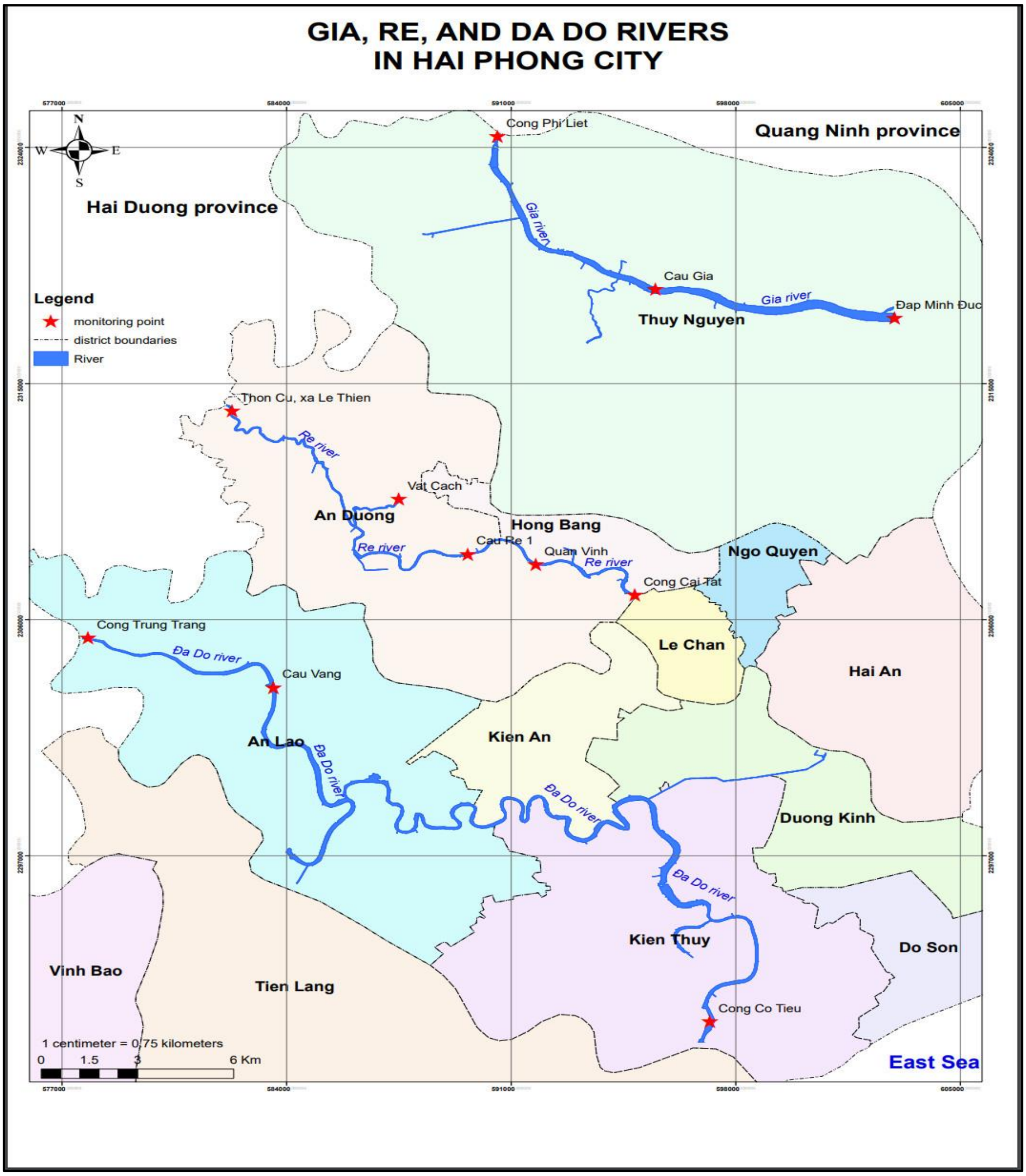

Figure 1. Map of Gia, Re and Da Do River systems in Hai Phong city.

Re River is the main canal route of An Kim Hai irrigation system, 20.6 km in length, starting from An Kim Hai canal at Bang Lai sluice (Ngu Phuc commune, Kim Thanh district, Hai Duong province) and ending at Cai Tat sluice (So Dau ward, An Duong district). The water consumption point is located at Quan Vinh Pumping Station, An Dong Commune, An Duong, Hai Phong. Functions of the Re River are irrigation for agricultural production; raw water supply for drinking water treatment; prevention of natural disasters, floods, and droughts; domestic and industrial wastewater recipient; and ecosystem protection. The Re River is currently polluted, where many indicators are exceeded, such as organic, Ammonium, Nitrite, Manganese, Total Iron, and Coliform. At the same time, the River has been affected by climate change, when sometimes there is not enough fresh water to replenish saltwater intrusion or increased pollution. All monitoring parameters exceed the allowable limit from 7% to 60%, especially Coliform and PO_4^{3-}_P [1].

Da Do River, the main canal route of the Da Do irrigation system, with a length of 48.6 km, originates from Trung Trang sluice (Quang Hung commune, An Lao district) and ends at Co Tieu sluice (Doan Xa commune, Kien Thuy district). The water collection point is located at Cau Nguyet Water Plant, Nguyet Ang village, Thai Son commune, An Lao district. The main functions of Da Do River are also raw water supply for drinking water treatment; irrigation for agricultural production; wastewater recipient; waterway transportation; and ecosystem protection. Da Do River has relatively stable water quality, but the risk of pollution is increasing, some indicators since parameters such as organic matter, Coliform tend to increase in the rainy season [1].

2.2. Methodology

2.2.1. Data collection

The topography, hydrology, hydraulics, concentration, and discharge loads (2018– 2020) were required as input for the water quality simulation model in the three rivers. Inputs for research include census report, reports on domestic activities, agriculture, industry, livestock and aquacultures, land use, and development planning up to 2030, extracted from the Hai Phong Statistical Yearbook [15].

2.2.2. Description of study modelling

Based on pollution load unit (PLU) and emission factor, pollution load was calculated to support further rapid assessment. There are two main types of pollutant discharge load for calculation: point source and area source. Using emission factors from [16–18] for various components including aquaculture area, wastewater discharge, population, number of livestock and poultry, etc., generated discharge load were computed, and environmental impacts were rapidly assessed. Four main sources of wastewater used for pollution load calculation were: domestic, industrial, livestock, and agricultural wastewater.

Waste load from domestic activities

Calculation from domestic waste source when fire-generating wastewater is connected to the water collection system and know the concentration value, wastewater flow at the wastewater treatment plant, the pollutant load from domestic wastewater can be calculated according to the actual discharge volume of the plant:

$$L = C \times Q \tag{1}$$

where L is the load (tons/year); C is the concentration of pollutants (mg/l); Q is the discharge flow (m^3/days).

For the case when there is no data on the concentration and discharge, the emission factor (source: WHO,1993) is used to calculate the discharge according to the following formula:

$$L_P = P \times PLU \tag{2}$$

where Lp is the pollution load generated (tons/year); P is the population; PLU is an emission coefficient.

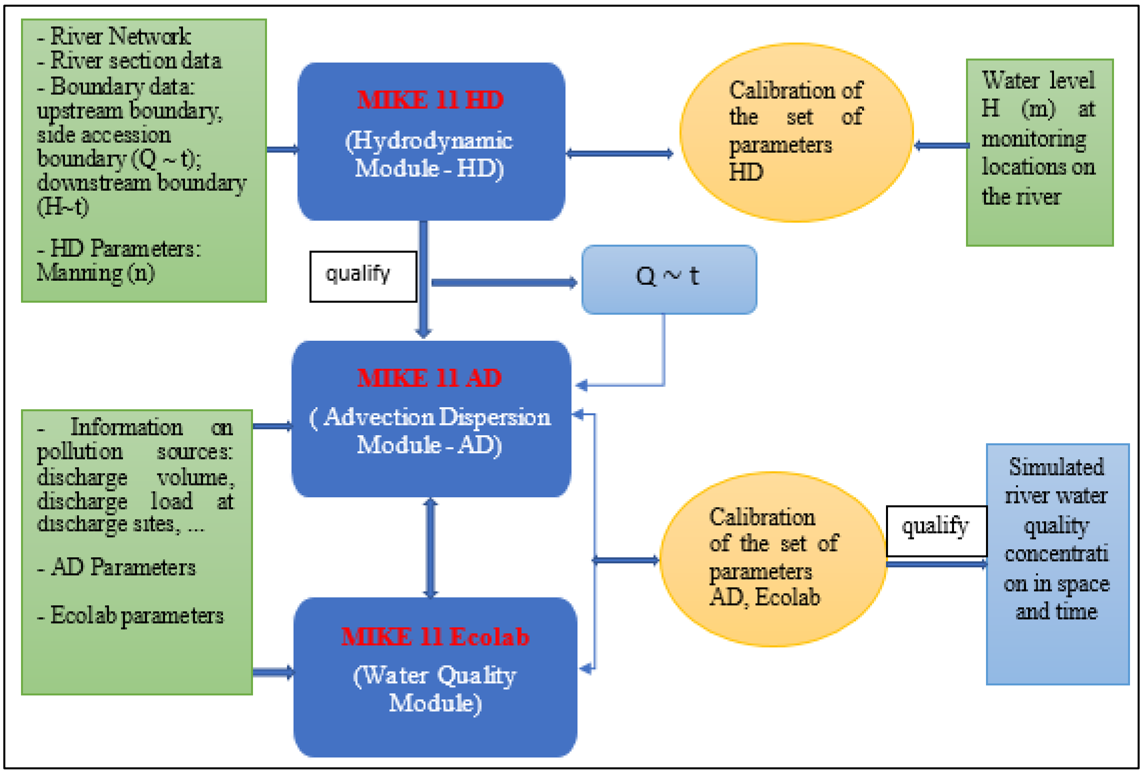

Figure 2. Research Methodology Diagram.

In the study, pollution loads from daily life were calculated in the areas of three rivers: Gia, Re and Da Do rivers. Waste load from domestic sources is based on WHO (1993) (formula 2), pollution from domestic waste generated by residents of riparian areas is calculated based on statistics on the number of inhabitants in each area. area and pollution emission coefficient per capita.

Waste load from industrial activities

The key industrial waste points are industrial parks and industrial clusters. In this study, industrial discharge load is determined based on actual measurement of wastewater concentration and flow as follows:

$$P_i = C \text{ x } Q \text{ x } 10^{-6} \qquad (3)$$

where Pi is the pollution load of each industry (tons/year); Q is the discharge volume (m^3/year); Ci is the concentration of wastewater (mg/l); the concentration of pollutants in industrial wastewater needs to be treated to meet QCVN 40:2011/BTNMT standards.

Waste load from livestock activities

For livestock production, waste is calculated from livestock, livestock and poultry production activities based on the annual total herd and the emission coefficients for livestock and poultry according to the following formula:

$$L = n \text{ x } PLU \text{ x } T/12 \qquad (4)$$

where n is the number of livestock/ poultry; T is an average rearing time year (month).

Waste load from cultivation activities

Based on the agricultural land area of each locality and from the pollution coefficient of rainwater runoff on the ground, based on the pollution coefficient according to WHO (1993) to calculate the amount of pollution. The formula for calculating the source of waste from soil leaching [19]:

$$Q_{rt} = S_i \text{ x } Q_i \text{ x } 10^{-3} \text{ x } n \quad (5)$$

where Q_{rt} is the contaminant load calculated for parameter i contained in stormwater runoff (ton/year); S_i is the current area of each type of land (km^2); Q_i is the pollution coefficient of rainwater runoff on the ground ($kg/km^2/day$); n is the number of rainy days in a year in the area (days).

Modeling approach

There are temporal and spatial variations in driving forces of flow in rivers, so hydrodynamic models are necessary to simulate flow regime in reality. This study applied one–dimensional hydrodynamic model (HD model) is MIKE11 with the core Saint–Venant equations which are written for each calculated node (Equation 7 and Equation 8) [20]. These equations are solved by six-point implicit scheme with initial and boundaries conditions.

Conservation of mass:
$$\frac{\partial Q}{\partial x} + b\frac{\partial h}{\partial t} = q \quad (6)$$

Conservation of momentum:
$$\frac{\partial Q}{\partial t} + \frac{\partial\left(\alpha\frac{Q^2}{A}\right)}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2AR} = 0 \quad (7)$$

where Q is the flow rate, h is the water level; t is the time; x is the distance variable; g is the acceleration due to gravity; A, b are the wet cross–sectional area and width; g is the acceleration due to gravity; α is the velocity correction factor; C is the Chezy coefficient; R is the hydraulic radius.

Water quality module

Advection–Diffusion module (AD module)

The calculated discharge, water level, cross–section area and hydraulic radius in HD model are used to model advection and diffusion of pollutants. The diffusion load equation reflects two transport mechanisms: (1) The process of transporting substances by flow (advection); (2) The process of diffusion of substances by turbulent flow (turbulent diffusion). The conservation of mass of a substance in a solution in AD module is described by the equation [20]:

$$\frac{\partial AC}{\partial t} + \frac{\partial QC}{\partial x} - \frac{\partial}{\partial x}\left(AD\frac{\partial C}{\partial x}\right) = -AKC + C_2 q \quad (8)$$

where C is the concentration (Kg/m^3); D is the diffusion coefficient; q is the unit flow rate (m^2/s); K is the biodegradation coefficient, K is used only when the phenomena or processes under consideration are related to biochemical reactions.

Ecolab module:

The ecological module in the MIKE 11 simulates the processes of bio–chemical development of water quality parameters (Template 4 in the MIKE 11 Ecolab module) with the following processes: heat exchange, transformation of organic matter, nitrogen change, phosphorus change, and oxygen change in rivers [20].

$$\frac{dT}{dt} = insolation - radiation \quad khi\ \ t \in \left[t_{up}\,; t_{down}\right]; \quad (9)$$
$$- radiation \qquad khi\ t \notin \left[t_{up}\,; t_{down}\right]$$

$$\frac{dBOD}{dt} = -BOD_{decay} \quad (10)$$

$$\frac{dNH_4\_N}{dt} = N\_BOD_{decay} - \text{Nitrification} \quad (11)$$

$$\frac{dNO_3\_N}{dt} = \text{Nitrification} - \text{Denitrification} \quad (12)$$

$$\frac{dOP}{dt} = \text{PPdecay} - \text{PPformation} + \text{OPreleaseFromBOD} - \text{OpplantUptake} \quad (13)$$

$$\frac{dPP}{dt} = -\,\mathrm{PPdecay} + \mathrm{PPformation} - \mathrm{PPsedimentation} + \mathrm{PPresuspension}$$

$$\frac{dDO}{dt} = \mathrm{Reaera} + \mathrm{phtsyn} - \mathrm{respT} - BOD_{decay} - SOD - Nitrification \quad (14)$$

where T is the temperature of water (^oC); insolation, radiation: Incoming solar radiation and the amount of radiation emitted by river water; BOD_{decay} is the BOD of dissolved organic matter (mg/l); K_{d3} is decomposition rate of dissolved organic matter (1/day); DO is the dissolved oxygen concentration (mg/l); NH_4 _N is an ammonium in terms of Nitrogen; NO_3 _N is the nitrate as Nitrogen, PP is the phosphorus flakes; OP is the soluble phosphorus.

3. Results and discussions

3.1. Calculation Results of Discharge Loads to Gia, Re, and Da Do Rivers

Discharge loads into the Gia, Re, Da Do Rivers were calculated based on 2020 statistics for various sectors. Waste load from domestic, industrial, livestock, and agricultural activities were accordingly presented in Table 1 to Table 4.

Table 1. Domestic waste load in Da Do, Re and Gia Rivers.

River	Location	Population (people)	Pollution load (ton/year)						
			COD	BOD_5	T_P	T_N	TSS	NH^{4+}	PO_4^{3-}
Da Do	Kien An District	119,388	6,566	2,985	131.3	477.6	3,582	262.7	70.92
	Duong Kinh District	60,345	3,319	1,509	66.4	241.4	1,810	132.8	35.84
	An Lao District	148,956	8,193	3,724	163.9	595.8	4,469	327.7	88.48
	Kien Thuy District	142,788	7,853	3,570	157.1	571.2	4,284	314.1	84.82
Re	An Duong District	198,661	10,926	4,967	218.5	794.6	5,960	437.1	118.00
	Hong Bang District	96,508	5,308	2,413	106.2	386.0	2,895	212.3	57.33
Gia	Thuy Nguyen	336,960	18,533	8,424	370.7	1348.0	10,109	741.3	200.20

Table 2. Industrial discharge load in Gia River, Da Do River, and Re river.

Wastewater receiving source	Total discharge volume (m^3/year)	Load of pollutants (tons/year)				
		BOD_5	COD	TN	TP	TSS
Gia	73,000	2.19	–	3.65	0.438	15.33
Da Do	255,135	11.71	31.00	10.21	1.530	53.58
Re	23,725	0.77	0.74	0.95	0.140	4.98

Table 1. Livestock discharge load on Gia, Re and Da Do rivers in 2020 (Unit: tons/year).

River		Re		Gia	Da Do			
District		Hong Bang	An Duong	Thuy Nguyen	An Lao	Kien Thuy	Kien An	Duong Kinh
BOD	Buffalo	–	0.08	0.03	0.08	0.11	0.00	0.01
	Cow	–	0.08	0.34	0.06	0.08	0.03	0.05
	Pig	0.003	0.12	0.25	0.12	0.25	0.02	0.06
	Poultry	0.001	0.35	0.43	0.43	0.34	0.02	0.09

River		Re		Gia	Da Do			
District		Hong Bang	An Duong	Thuy Nguyen	An Lao	Kien Thuy	Kien An	Duong Kinh
COD	Buffalo	–	0.14	0.05	0.15	0.19	0.00	0.02
	Cow	–	0.15	0.61	0.11	0.15	0.06	0.09
	Pig	0.03	1.08	2.23	1.08	2.22	0.15	0.55
	Poultry	0.25	64.36	79.01	79.29	61.90	3.45	15.61
T_N	Buffalo	–	20.41	7.53	22.56	28.34	0.18	2.23
	Cow	–	21.55	89.83	16.43	21.55	8.58	13.27
	Pig	0.69	26.83	55.12	26.68	54.86	3.61	13.72
	Poultry	3.09	785.44	964.21	967.55	755.38	42.08	190.44
T_P	Buffalo	–	5.27	1.94	5.82	7.31	0.05	0.58
	Cow	–	5.56	23.18	4.24	5.56	2.21	3.42
	Pig	0.22	8.45	17.37	8.41	17.28	1.14	4.32

The pollution sources from livestock production have the largest TSS discharge load and the smallest total phosphorus unit load of all calculated parameters. In Gia and Da Do Rivers, TSS discharge accounts for the largest pollutant load (6,978–13,929 tons/year).

Table 4. Agricultural discharge loads on Re river, Gia River and Da Do River.

River	District	Area of agricultural land (km^2)	Agricultural waste load (tons /year)				
			COD	BOD_5	T_N	T_P	TSS
Re	An Duong	49,794	206.00	133.00	265.00	59.00	18,423.78
	Hong Bang	1.159	5.00	3.00	6.00	1.37	428.83
Da Do	An Lao	53.68	222.45	143.00	286.01	63.56	19,861.60
	Kien An	7,766	32.18	20.69	41.38	9.19	2,873.42
	Duong Kinh	13.33	55.24	35.51	71.02	15.78	4,932.10
	Kien Thuy	50.32	208.5	134.05	268.10	59.58	18,618.40
Gia	Thuy Nguyen	91,448	294.46	189.29	378.6	84.13	26,291.3

The waste from agricultural activities released into the three rivers has a total volume of 94,720.48 tons/year in 2020. The Da Do River bears the largest agricultural load compared to the Re and Gia rivers, since agriculture is the most active in Da Do basin. The number of COD, TN, and TSS is almost one and a half to two times higher than that of the other two rivers. Meanwhile, Re River has the lowest load of substances.

3.2. Simulation Results of Water Quality in Gia, Re, and Da Do Rivers

The network of Gia, Re, and Da Do Rivers in the simulation model are shown in Figure 3. The results of hydraulic calibration of three rivers in the period of 2020–2021 gave relatively good results with the Nash coefficient NS = 0.72–0.88, the model verification process was simulated from January 1, 2022 to May 30, 2022 with time step results of NS = 0.7–0.82. Afterwards, the MIKE 11 Ecolab module was constructed to simulate water quality on Gia, Re, and Da Do Rivers at three locations along Gia River, five locations along Re River, and three locations along Da Do River (Figure 7). The network of Gia, Re and Da Do rivers in the simulation model as shown in Figure 3. Simulated results were verified by comparing with monitoring data of 4 water quality indicators in April 2020, shown in Figures 4 to 6.

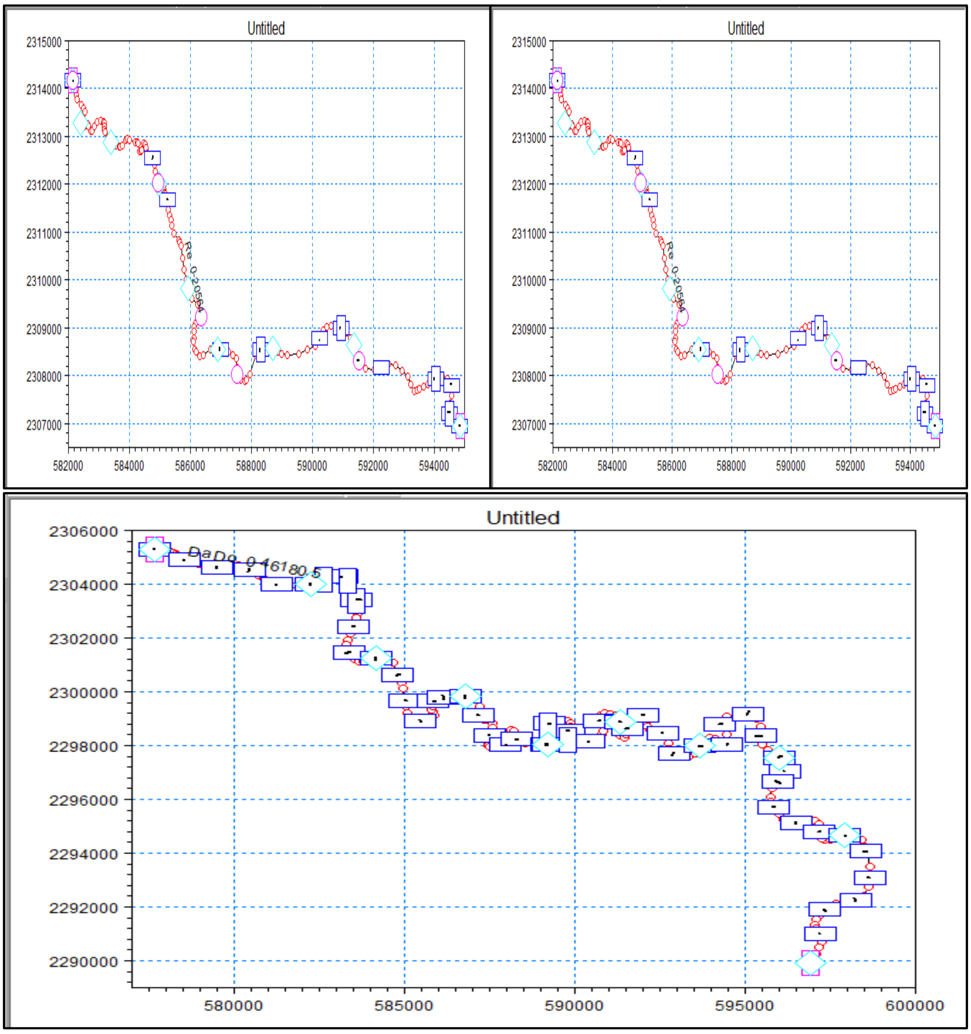

Figure 1. The Gia (Left), Re (Right), and Da Do (Bottom) river networks are used in the MIKE 11 model.

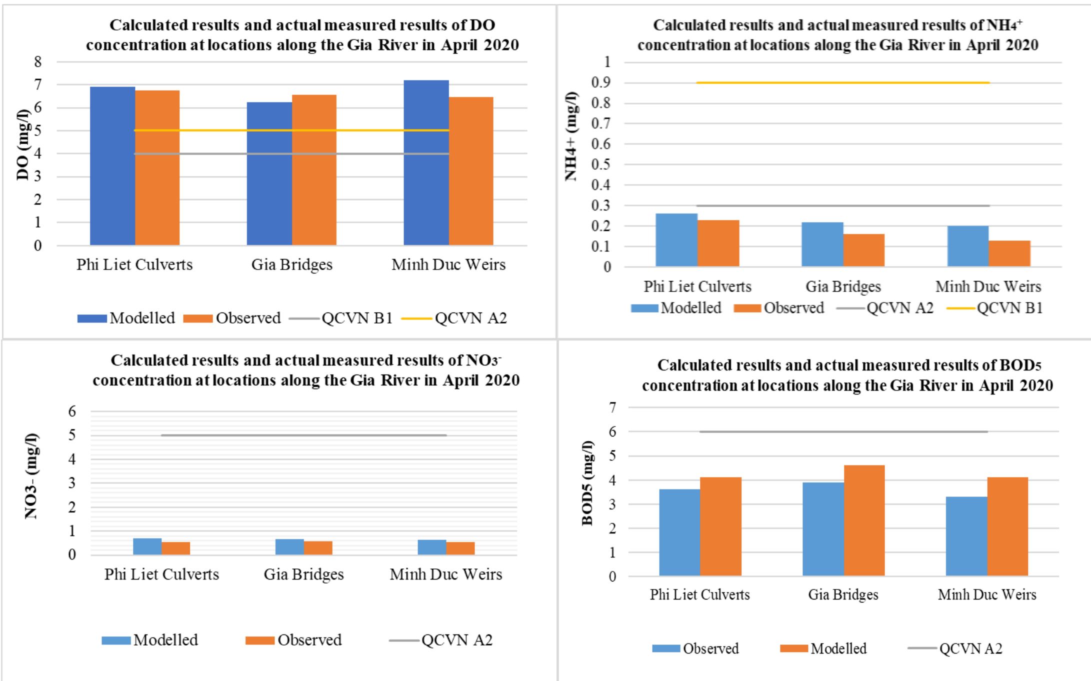

Figure 2. Calculated results and measured concentrations of DO, NH_4^+, NO_3^- and BOD_5 concentration at locations along the Gia River in April 2020.

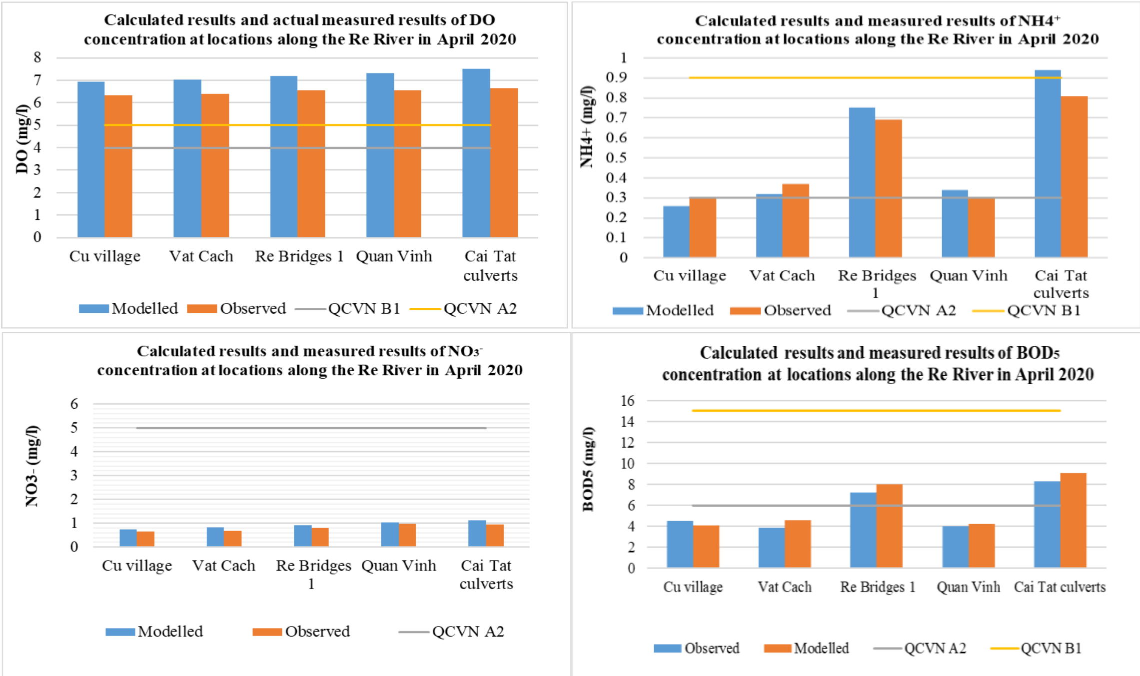

Figure 3. Calculated results and measured concentrations of DO, NH^{4+}, NO^{3-} and BOD_5 concentration at locations along the Re River in April 2020.

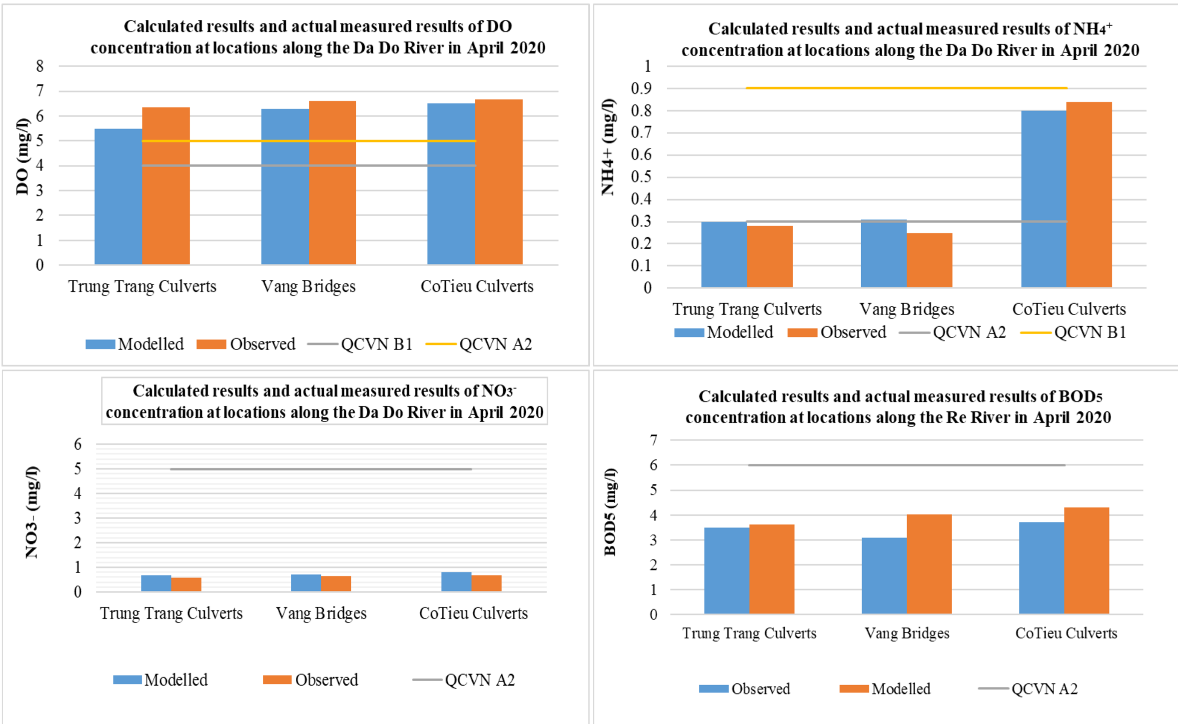

Figure 4. Calculated results and measured concentrations of DO, NH^{4+}, NO^{3-} and BOD_5 concentration at locations along the Da Do River in April 2020.

Figures 4 to 6 compares the measured and simulated concentrations with the National Technical Regulations on Surface Water Quality Category A_2 (For domestic water supply purposes accompanied with application of suitable treatment technology or uses described in Categories B_1 and B_2) and B_1 (For irrigation or other uses with similar water quality requirements or uses described in Category B_2). The calculation results compare the relative error between the measured and simulated values on three rivers, ranging from 4 to 18%, the correlation coefficient R_2 ranging from 0.8 to 0.88. This confirms that the simulation model is relatively good and suitable for simulating water quality progression in the three rivers. More importantly, comparison between water quality concentrations and the standard shows that all 3 locations of Phi Liet culverts, Gia bridges, Minh Duc weirs in Gia river have good water quality, meeting A_2 standard. Meanwhile, on the Re River, the concentration of NH_4^+ at all locations exceeds the A_2 standard, specifically more than 2 times higher at Re bridge and Cai Tat sluice. Also, at these two locations, the BOD_5 concentration also exceeded the standard A_2. Lastly, on Da Do River, the concentration of NH_4^+ at Co Tieu culverts exceeded the standard A_2 by 2.8 times. In large, pollution occurs locally at Re bridge, Cai Tat sluice on the Re River, and Co Tieu culverts on Da Do River, with high NH_4^+ concentration. This is probably due to the wastewater discharge from nearby industrial parks, industrial clusters, and hospitals, or from agricultural activities. Therefore, to use these water sources as drinking water supply, it is necessary implement wastewater controls along the rivers to improve river water quality.

The WQI water quality index was calculated based on five groups of water quality parameters [21–24]. In this study, we focus on four groups of parameters I, III, IV, and V. The monitoring data of the above four groups combined with simulation data from the MIKE model, the research team calculates the WQI at 11 locations on three rivers, as shown in Table 5 below.

Table 2. WQI water quality index results on Gia, Re and Da Do rivers.

River	Observation location	Coordinates		Average Annual WQI				
		X	Y	2016	2017	2018	2019	2020
Gia	Phi Liet culvert	593519	2307719	96	95	92	66	99
	Gia bridge	590449	2324041	96	95	88	92	99
	Minh Duc weir	595266	2318707	89	44	96	95	95
Re	Cu village, Le Thien Commune	582303	2313965	95	95	85	38	94
	Vat Cach	587504	2310602	95	95	98	79	94
	Re bridge 1	589655	2308508	94	74	87	36	82
	Quan Vinh	591773	2308098	90	87	81	39	94
	Cai Tat culvert	589614	2280568	83	85	40	38	75
Da Do	Trung Trang culvert	577818	2305313	95	96	93	97	98
	Vang bridge	583599	2303427	45	81	96	42	98
	Co Tieu culvert	597200	2290674	98	97	87	83	80

Table 3. Range of values for assessing surface water quality.

WQI value range	Water quality	Fit for the intended use	Color
91–100	Very good	Good use for domestic water supply	Blue
76–90	Good	Used for domestic water supply but require appropriate treatment measures	Green
51–75	Medium	Used for irrigation and other equivalent purposes	Yellow
26–50	Least	Used for waterway transportation and other equivalent purposes	Orange
10–25	Heavy pollution	Water is heavily polluted, require future treatment measures	Red
< 10	Pollution is very heavy	Poisoned water, require mistake measures to treat and revert	Brown

The calculation results of the water quality index of Gia River, Re river and Da Do river show that the water quality in 2020 at most control locations was better than in 2019. Water quality in Gia River was assessed as very good quality, which can be used for domestic water supply. Re and Da Do Rivers were also polluted by several waste sources, so from the middle to the lower reaches of the river, the water source was of average to good quality, suitable for domestic water supply purposes with appropriate treatment measures and for irrigation and other equivalent purposes.

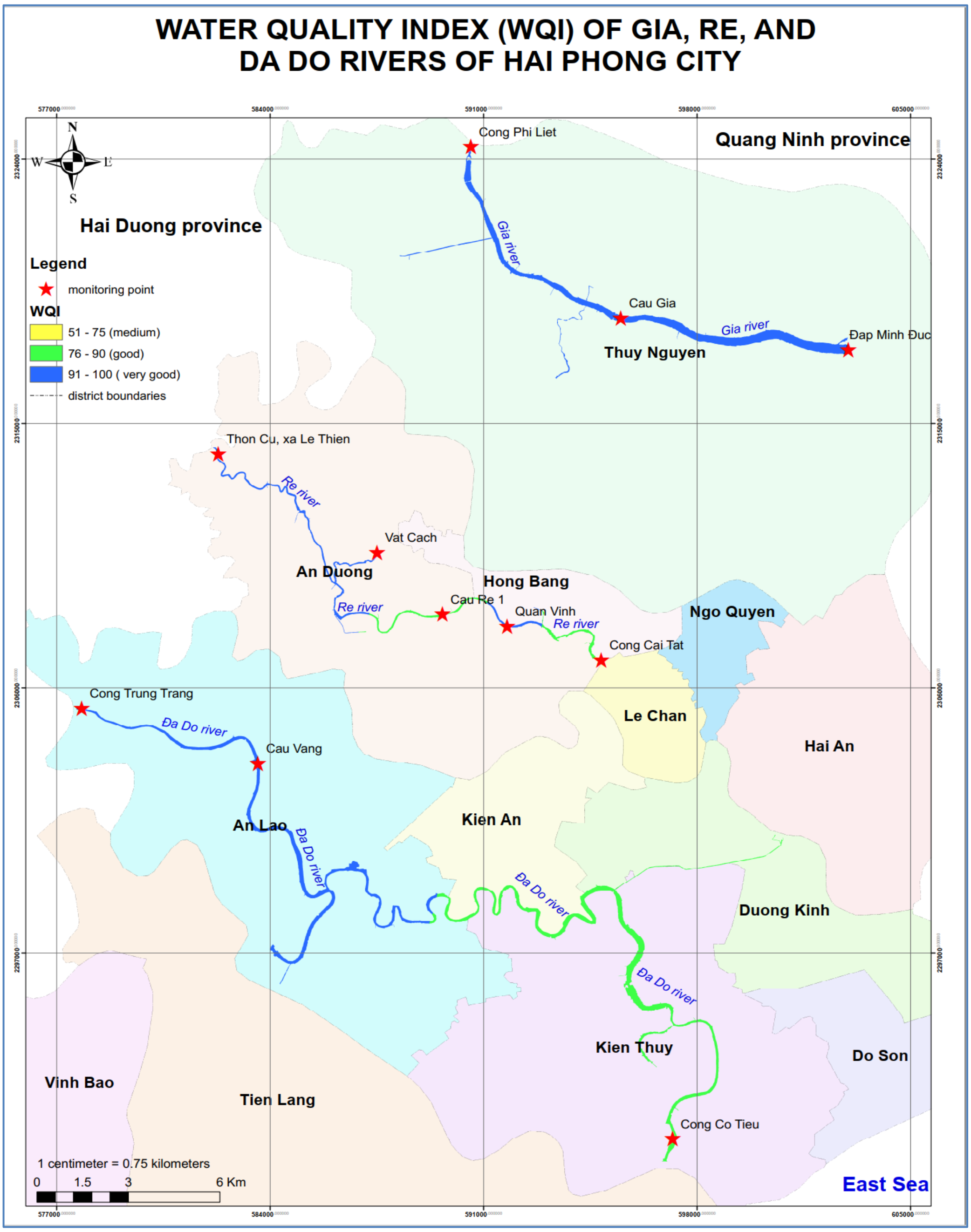

Figure 5. Map of WQI water quality index on Gia, Re and Da Do rivers in Hai Phong city.

4. Conclusion

In this paper, the research team presented the method and calculated the pollutant discharge load, water quality changes in Gia, Re, Da Do rivers using the MIKE 11 Ecolab model, showing the pollution level of each water quality index at different locations on the rivers. Concurrently, WQI index was calculated from the combination of simulation results and measured water quality to assess river water quality. Based on the results of water quality calculations at different locations on the Gia, Re and Da Do Rivers, the water quality by 2020 has improved significantly comparing to 2019, while some of the leading canals, lakes, and outlets on the Re and Da Do Rivers are still polluted by organic substances and microorganisms. Water quality in the Re River is generally of average quality, which can be used for irrigation and other equivalent purposes. More notably, the water quality at all canals, discharge gates and river sections in receiving wastewater from landfills in these three networks show signs of pollution by organic substances, nutrients, microorganisms, etc. Therefore, to protect water sources of the Gia, Re, and Da Do Rivers systems, it is necessary to implement effective management and treatment measures for the entire system and proper planning for sustainable economic development for surrounding households and businesses.

In this study, the studied rivers are three small rivers in Hai Phong city, so the hydrological, hydraulic and water quality data is limited. The flow modeling process sometimes cannot be simulated for a long time. Therefore, future research for these rivers may take advantage of artificial intelligence models to supplement missing data. Moreover, research for the implementation of automatic water quality monitoring system in these rivers should be conducted for spatial and temporal water quality assessment.

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